Science as Culture

ISSN: 0950-5431 (Print) 1470-1189 (Online) Journal homepage: www.tandfonline.com/journals/csac20

Mammoths and tigers and rhinos, oh my: mapping de-extinction species and networks

Avey Nelson & Kate O'Riordan

To cite this article: Avey Nelson & Kate O'Riordan (12 Mar 2025): Mammoths and tigers and rhinos, oh my: mapping de-extinction species and networks, Science as Culture, DOI: 10.1080/09505431.2025.2473882

To link to this article: https://doi.org/10.1080/09505431.2025.2473882

Published online: 12 Mar 2025.

SCIENCE AS CULTURE
https://doi.org/10.1080/09505431.2025.2473882

Mammoths and tigers and rhinos, oh my: mapping de-extinction species and networks

Avey Nelson[a] and Kate O'Riordan [b]

[a]Faculty of Media, Arts and Humanities, University of Sussex, Brighton, UK; [b]Department of Media and Film, University of Sussex, Brighton, UK

ABSTRACT

De-extinction initiatives targeting species like the woolly mammoth, thylacine, and northern white rhino reinscribe neocolonial networks through the extraction and circulation of resources. These projects leverage conservation narratives to legitimise biotechnological advancements, driving biomaterials, data, and capital to and from regions such as Siberia, Tasmania, and Kenya to Western technoscientific centres. A postcolonial science and technology studies (STS) framework demonstrates that conservation and biotechnology operate in tandem to reproduce historical patterns of geopolitical control by commodifying life and marginalising local sovereignty. Simultaneously, feminist STS emphasises how reproductive technologies in de-extinction – such as assisted reproduction and genetic engineering – reinforce power dynamics by controlling reproduction and regulating populations, transforming life into economic capital. Together, these frameworks illuminate the ways that contemporary technoscience continues to reproduce colonial patterns by managing life and resources through biotechnological interventions.

ARTICLE HISTORY
Received 17 March 2023
Accepted 17 January 2025

KEYWORDS
De-extinction; postcolonialism; neocolonialism; conservation; biotechnology

Preamble: lions and tigers and bears

When faced with the unknown manifested as a dark forest, Dorothy, the protagonist of the 1939 film *The Wizard of Oz*, seeks to contextualise it: 'Lions and tigers and bears, oh my!' The phrase refers not only to that which is unknown, but also uncountable, likely dangerous; with a sense of apprehension. It does so through the language of animals. The phrase resonates throughout media and culture. In his science fiction trilogy, *Hyperion Cantos*, Dan Simmons cites this: 'The metasphere remains. But it is more wilderness than ever now. Black forests

CONTACT Kate O'Riordan K.ORiordan@sussex.ac.uk Faculty of Media, Arts and Humanities, University of Sussex, Brighton, BN1 9RG UK

of unknown time and space. Sounds in the night. Lions. And tigers. And bears' (Simmons, 1991). Here, the eponymous animals signify post-human entities, blending artificial intelligence, interplanetary consciousness, and the promise of singularity. The animals are defamiliarised, and the unknown remains. We borrow the tiger's coincidental reference to the thylacine to gather mammoths and rhinos as a parallel triptych for thinking about de-extinction.

Introduction

De-extinction, or the process of recreating extinct species through biotechnology, has developed both as a scientific possibility, and a controversial topic across academia and the media. It has emerged as a transdisciplinary area of study, engaging the biosciences, earth sciences, social sciences, and humanities, while drawing attention in policy and ethics. The launch of Colossal Biosciences in 2021 catalysed this, bringing de-extinction, its histories, and its potential implications into the public spotlight. Once confined to niche scientific circles, de-extinction now features in mainstream news, with discussions of the ethics and logistics of reviving mammoths, the thylacine's tragic past, and the science's role as a conservation tactic (Katz, 2022).

More technically, de-extinction refers to creating (and propagating) proxies of extinct species using advanced biotechnological methods (Katz, 2022). However, the term extends beyond genomic resurrection, occupying a liminal space where speculative science meets practical application to construct imaginaries that are 'very much real' (Searle, 2020, pp. 337–338). We use specific terms to navigate de-extinction's complex landscape: De-extinction actors are entities (e.g. labs, universities, museums, non-governmental organisations, conservation initiatives, etc.) that influence and shape de-extinction practices and outcomes within a network. De-extinction networks encompass the complex flows of money, resources, materials, data, and intellectual property among actors, shaping the power dynamics within de-extinction initiatives. While the de-extinction's target outcome is on the horizon, its actors and networks work through historical systems to operate in and impact the present.

We take a postcolonial, feminist science and technology studies (STS) approach to de-extinction, examining it through the following research questions: What networks emerge when we map de-extinction actors? How do these networks reflect historical colonial patterns? How do conservation initiatives and biotechnological developments reinforce these flows of power? Addressing these questions, we argue that de-extinction functions as a neocolonial technoscientific apparatus, which is predicated on and reproduces historical colonial patterns. De-extinction initiatives promote a saviour narrative, promising that biotechnology will offer reparation for the destruction of climate, people, and species. Yet, this promise is underpinned and undermined by an emphasis on advancing biotechnology as a means of geopolitical control. Our mapping and analysis suggest that these networks re-enact colonial relationships, positioning Western institutions as centres of scientific research and innovation that extract resources (biological, digital, and ultimately financial) from historically colonised sites. Through this framework, de-extinction initiatives recast biotechnological advancements as tools for conservation and reparation, marshalling resources and rationalising these initiatives.

We introduce as case studies three candidates of different species, scale, and status: the woolly mammoth, the thylacine, and the northern white rhino. These species are correlated with, and interconnect, sites across Siberia, Alaska, Australia, Tasmania, Kenya, parts of Europe, the United Kingdom, and the contiguous United States. Our methodological approach integrates Bruno Latour's Actor-Network Theory (ANT) and Noortje Marres's issue mapping, employing digital and material methods to trace the contemporary pathways of de-extinction alongside historical colonial trajectories. Each section of our empirical analysis considers a specific candidate species, detailing its natural and symbolic history, as well as its region's colonial and conservation history. We examine the corresponding de-extinction initiative, including the actors, networks, and biotechnology involved. Through this mapping, we illustrate how these initiatives reflect and perpetuate neocolonial dynamics. We conclude by synthesising our findings across species, critiquing the speculative futures of de-extinction initiatives while emphasising their material and neocolonial implications.

Analytical perspectives

Integrating postcolonial and feminist STS allows for a combined analysis of colonial power relations and reproductive (bio)technologies. Applying these analytical approaches to de-extinction initiatives is generative because they advance reproductive biotechnologies by conserving and extracting resources from historically colonised sites. De-extinction is a feature of postcolonialism, reproducing colonial flows while redrawing neocolonial ones through its conservation and biotechnology aims.

While conservation provides an ideological justification for de-extinction, biotechnology furnishes its initiatives with resources, funding, and power through bioprospecting, advancing genetic and reproductive technologies. From a feminist perspective, we consider de-extinction as a cluster of neocolonial reproductive biosciences, illustrating and discussing its reach and impact in our mapping and analysis. Situating de-extinction as both neocolonial and reproductive demonstrates the mechanisms and effects of contemporary global initiatives, which exert control over knowledge, resources, land, animals, and people.

Each de-extinction project that we discuss was historically constituted through nineteenth-century Western imperialism. For the mammoth, remains are extracted from Siberia, with one imagined re-introduction site in Alaska. Although Russia colonised Siberia, it sold Alaska to the United States in 1867, giving the 'traditional West' – economist Peter Watkins's term (qtd. in Prasad, 2022) for the United States, European Union, and United Kingdom – a foothold in the region. Similarly, Britain colonised areas linked to the extinction, extraction, and re-introduction of both the thylacine and the northern white rhino: Tasmania in 1803 and Kenya in 1901. Western nations continue to exert imperial power through technoscientific development, operating via institutions like research centres, cultural heritage bodies, and NGOs. Britain, in particular, has maintained political, economic, social, and technological influence in these regions long after their independence. The United States and Australia, shaped by their own histories of British colonisation, have consequentially emerged as centres of neocolonial power.

This influence is reflected in postcolonial STS perspectives on colonialism's lasting impact. As Amit Prasad argues, 'to situate European colonialism simply in the distant past is to ignore that individuals as well as societies/nations are discursively constituted and imagined through historical experiences' (2022, p. 10). De-extinction exemplifies this constitution, as the regions targeted for species revival and the underlying power dynamics of these projects remain shaped by colonial legacies. Sandra Harding, in her examination of the convergence and dissonance between postcolonial and feminist STS, refers to this as the 'residues and resurrections of colonial and imperial science and technology relations' (Harding, 2009, p. 405). These 'residues and resurrections' of colonial science illustrate how de-extinction, like other technoscientific projects, reinforces historical power structures that, as Prasad argues, actively shape both societies and ecosystems.

Emerging from colonial capitalism, Western technoscience is positioned as the prevailing 'fix' for colonial extinctions, climate change, and biodiversity loss. Feminist STS critiques both aspects of this approach: the universal authority and the technological fix. Harding (1998, p. 184) argues this approach legitimises a single authoritative science. In de-extinction, biotechnology embodies this, promising conservation, climate justice, and advances in human-assisted reproduction and genetic disease cures. These narratives of technoscientific development obscure the flows of resources, materials, data, finances, and labour essential to this development, as well as the control over geopolitical power dynamics and reproduction embedded in these flows.

Extinction poses a central problem in conservation initiatives, rendering de-extinction a tempting solution. A publication from the International Union for Conservation of Nature (IUCN) Species Survival Commission (SSN) (2016) reflects the tension that emerges within de-extinction as the science moves closer to reality. It identifies the potential benefits of restoring biodiversity, enhancing ecosystem function and resilience, engaging public support, and advancing technology. The mammoth de-extinction initiative, for instance, promises to combat climate change by 'restoring habitats for carbon absorption and sequestering' (Colossal, 2024). However, the IUCN also highlights potential disadvantages, including financial and opportunity costs, decreased support for preventing extinctions, risks to the welfare of the animals involved, post-release issues (e.g. invasiveness, novel disease vectors, revival of ancient pathogens, etc.), ecosystem and socio-economic impacts, and re-extinction (ICUN SSN, 2016). Ecology scholars echo these concerns, with Iacona et al. (2017) emphasising the financial strain de-extinction could introduce by diverting funds from already economically disadvantaged existent species management programmes, and Genovesi and Simberloff (2020) cautioning about the ecological impact of releasing invasive 'proxy' species in environments that have long since evolved in their absence. De-extinction's controversial role in conservation intersects with its colonial history.

Conservation, embedded in de-extinction, carries these colonial legacies alongside postcolonial implications. De-extinction's mission of ecological revival is theoretically de-colonial in that it seeks to repair the ecological damage caused, in part, by colonisation. However, Kashwan et al. (2021) remind us that 'colonialism and racism are etched in the dominant philosophy, models, and institutional apparatus of global conservation'. They specifically warn of 'exclusionary conservation,' where protected species are kept on legally protected land. This model often financially benefits external Western NGO, conservation, and tourism industry actors, while excluding regional and Indigenous peoples from these benefits. Indigenous peoples, with traditional ties to their lands and generational knowledge of its stewardship, are frequently disenfranchised or displaced in the name of development interventions aimed at environmental protection. These systemic features of conservation further exploit those who have been denied access to their livelihoods, land, and resources, while often undermining explicit conservation goals. Zaitchik (2018) describes this as a 'double failure' and part of the 'complicated legacy of the modern conservation movement'. As a mechanism of conservation, de-extinction is part of these colonial legacies and ongoing impacts.

If conservation is de-extinction's ideological cadaver, primed to be charged with new life – or lives – then biotechnology supplies this charge, this lifeblood. Advancing biotechnology remains a key objective of de-extinction, positioning Western technoscience as the solution to ecological and genetic challenges. For resurrection or conservation, de-extinction requires substantial bioprospecting (identifying and collecting biological materials) and biobanking (storing biological materials). This is framed as 'the intentional and indefinite preservation of living cells from wildlife, for the purposes of safeguarding genetic diversity and enabling genetic rescue' (Revive and Restore, 2024). For instance, Colossal holds cell line from elephant, marsupial, and other species, and the San Diego Frozen Zoo's collection contains over 10,000 living cell cultures, oocytes, sperm, and embryos, (San Diego Zoo, 2024). These libraries enable de-extinction projects to advance genome sequencing for extinct species, through the use of ancient DNA, and existent species.

Over the past two decades, developments in computational biology have enabled scientists to store and process billions of data points from whole genome sequences, apply algorithmic pipelines for pattern matching, and edit genomes (Cabral, 2019; Yin et al., 2019). Genome editing accelerates genetic engineering technologies, particularly with CRISPR-Cas9 systems, editing the genome of existing species to resemble that of extinct ones. CRISPR is also applied to human therapies, including treatments for genetic diseases. When used alongside induced pluripotent stem cells (iPSCs), or stem cells derived from somatic cells, it allows scientists to create facsimiles of lost species' gametes, further advancing assisted reproduction across species.

De-extinction, as a reproductive science, demands engagement with feminist STS scholarship, particularly concerning assisted reproductive technologies (ART) like *in vitro* fertilisation (IVF), surrogacy, cloning, and genetic engineering. Reproductive sciences, including de-extinction, are central to biopolitics, as they produce and regulate populations while controlling the means of their reproduction. Feminist STS highlights how these technologies are embedded in (gendered) power structures, shaping both human and non-human reproduction. De-extinction is part of a broader network of biotechnologies, with IVF at its core, enabling the flow of both human and non-human animal eggs, embryos, and oocytes. As feminist STS scholar Sarah Franklin (2013) puts it:

> From an experimental research technique used in embryology, IVF has evolved into a global technological platform, used for a wide variety of applications, from genetic diagnosis and livestock breeding to cloning and stem cell research.

De-extinction, like other reproductive sciences, applies methods and materials across species, blurring distinctions between human and non-human reproductive technologies. This cross-species exchange aligns with what Franklin calls *transbiology*:

> … transbiology is also made up out of the complex intersection of the pure and the impure, where quality and biological control are literally merged to create new kinds of organisms (Franklin, 2006, 176)

Originally developed for animal husbandry, the IVF/stem cell nexus entered human reproduction in the early 2000s. It plays back through reproductive de-extinction 20 years later. De-extinction is an ART that claims to operate at the species level, yet it is actualised through individual animal bodies.

De-extinction, then, maps out across both neocolonial power dynamics and a network of post-Dolly mammalian biology (Franklin, 2007). Practically, it develops ARTs to revive its target candidate species; speculatively, it develops them for widespread use across species. In cases like the northern white rhino, scientists either harvest gametes from living or deceased animals or produce artificial gametes through stem cell-associated techniques (SCAT), such as induced pluripotent stem cells (iPSCs). They use these gametes to fertilise harvested oocytes, and they transfer the resulting embryo to a surrogate using IVF. Projects like the mammoth and thylacine propose using CRISPR to genetically engineer an embryo before bringing it to term through IVF and surrogacy. These techniques' wider applications include advancements in ARTs and SCATs, genetic disease research across species, and generating new biological combinations. While conservation might be a speculative aim for de-extinction, its real and immediate impact is on the fields of biotechnology and assisted reproduction.

Biotechnology is an artefact of colonial history, based on the extraction and circulation of tissues, or life itself (Waldby and Mitchell, 2006; Franklin, 2013). The advancement of de-extinction technologies requires a reproductive neocolonial biomaterial economy, involving the collection, storage, and use of biological materials from various species (Waldby and Mitchell, 2006). De-extinction research relies on the extraction and flow of biomaterials from sites shaped by histories of colonisation and settlement, such as Siberia, Tasmania, and Kenya. Mammoth remains, living white rhino cells, and thylacine specimens circulate through labs in the United States, Australia, and Europe. This often depends on the labour of regional or Indigenous workers, who are exploited through economic disparity. For instance, Christian Frei and Maxim Abugaev's documentary *Genesis 2.0* (2018) details the brutal conditions faced by mammoth tusk hunters working for commission. Ultimately, de-extinction practices perpetuate historical injustices by continuing the exploitation of marginalised communities and their environments for scientific gain.

Our postcolonial analysis of de-extinction's driving forces – conservation and biotechnology – enables a systemic understanding of de-extinction as a neocolonial apparatus. We use neocolonialism in this context to frame the reproduction of power relations, previously exercised through colonial military or governmental processes, now perpetuated through contemporary technoscience. These neocolonial patterns play out in relation to each region's history. In our postcolonial initiative to recentre the margins, we examine how these candidate species occupy a historical and geographical trajectory shaped by colonial and neocolonial power relations.

Candidate species

We explore three de-extinction candidate species that, after approximately 55 million years of evolution, became extinct in relation to poignant moments in relatively recent human history. As Searle (2020) notes, 'extinctions […] are difficult to locate, define, understand or even imagine'. Mammoths are the oldest figure in our triptych. Their extinction, which arguably occurred across various subspecies between 4,000 and 11,000 years ago, played out at the cusp of human prehistory and recorded history (Miller, 2022). However, their historical trace remains, and their genomes live on through sediment and deposits, the Asian elephant, and synthetic genomics. The Tasmanian Tiger, which is not a tiger, but a carnivorous marsupial known as the thylacine, has gained momentum as a key candidate in the spectacle of de-extinction due to the project's viability. Living thylacines have co-existed with twentieth-century humans, with the last known animal dying in captivity in 1936. The northern white rhino is our third figure. Northern white rhinos are not technically extinct; at the time of writing, two animals are living in the Ol Pejeta Conservancy in Kenya. However, the species has long passed its extinction threshold. It is only virtually extant, with its genetic materials existing in suspension as cryopreserved embryos and eggs.

Despite their extinct status, all three species still exist within media and biomaterials. Mammoths figure as a universal cipher of a global de-extinction imaginary, with traces, including prehistoric media, spanning three continental formations (Europe, Asia, and North America) in contemporary geopolitics. However, their actual inhabitation before extinction belonged to a vastly different temporal and geographical reality. Wrigley (2023) examines this difference in terms of 'discontinuity' through an ethnography of the permafrost, which global warming has rendered impermanent, bringing mammoth remains into a different era. Scientists understand thylacines as indigenous and specific to Tasmania and the Australian mainland, yet thylacine remains are preserved across five continents. The last remaining northern white rhinos are currently in Kenya, perceived as animals of northern sub-Saharan Africa. Until recently, however, these last animals of the species lived in zoos in the United States and Europe. Their biomaterials also exist as cryopreserved embryos, eggs, sperm, and other tissue samples in laboratories in Italy, Germany, and the United States.

We consider the cultural weight and scale of each species, the history of its extinction, the initiatives surrounding its de-extinction, the circulation of biomaterials involved in each initiative, and the technology developed for its resurrection. We map each species' key actors and networks, identify points of intersection between these networks, and illuminate the neocolonial patterns that emerge within and between them.

Methods

We identify the leading actors involved these de-extinction projects and chart the networks in which they operate. We do so by examining organisational websites, press releases, scientific studies, and affiliated literature. Specifically, we locate the labs that host these projects, their affiliated and partner organisations, facilities that store biomaterials, the imagined origin sites where these extinct species once lived, and the imagined habitats where the revived species will be (re)introduced.

Here, we draw on actor-network theory (ANT) and issue mapping as our methodological frameworks. Bruno Latour (2005, p. 166) posits that actions are never localised, observing 'any given interaction seems to overflow with elements which are already in the situation coming from some other time, some other place, and generated by some other agency'. Further highlighting that 'action is always dislocated, articulated, delegated, translated,' Latour's perspective articulates how actions are interconnected and mediated through spatial and digital networks. Noortje Marres's (2015) understanding of issue mapping extends ANT, enabling us to visualise the complex networks that form through these dislocated actions. Issue mapping allows us to trace and represent the networks that emerge through such dislocations, employing digital and material methods to delineate the relationships and flows among actors and materials involved in de-extinction. This method clarifies the political geographies that shape these relationships and the spatial and temporal dynamics of these networks. By mapping de-extinction actors, including labs, partner organisations, and facilitates that store living organisms, remains, and reproductive materials, we illuminate the neocolonial trajectories embedded within these technoscientific networks.

Considering Latour's understanding of non-human actors, we also map the biomaterials circulating within de-extinction networks. As Bowker and Star (1999, p. 5) note, the creation of classification systems is a fundamental aspect of the built information environment, inherently carrying a moral and ethical agenda due to the often-invisible nature of effective classifications. Our approach intentionally brings these classifications to the forefront to critically expose the neocolonial biomaterial economy underpinning de-extinction research. We categorise biomaterials across a spectrum of liveness, which includes: (1) extinct or threatened animal remains, detailing both the sources and the collections where they are stored; (2) viable or potentially reproductive materials (e.g. eggs, sperm, embryos, genomes, cell lines, etc.); and (3) living organisms, encompassing both the last remaining animals of a species and extinct animals' living relatives involved in research.

The nodes on our map represent the locations where various actors in the de-extinction network operate, and through which the biomaterials circulate. To conduct our initial research and develop the underpinning digital maps (Appendix), we categorised each node according to the following roles and functions:

- Labs: The labs conducting de-extinction initiatives and research.
- Organisations: Entities partnered or affiliated with the labs.
- Habitat (Extinct): The imagined natural habitat of the extinct animal.

- Habitat (De-Extinct): The habitat in which the revived species will be introduced.
- Remains (Source): The locations where the animal remains are excavated, often overlapping with – and drawing a material connection between – the extinct habitats.
- Remains (Storage): Collections where the remains of extinct species are stored.
- Reproductive Materials (Storage): Facilities where reproductive materials (e.g. eggs, sperm, embryos, genomes, cell lines, etc.) are stored.
- Living Organisms: Locations of the living animals that are used in de-extinction research. We distinguish them by their role (e.g. candidate, surrogate species, etc.).

We take a dual approach to mapping the actors involved in de-extinction and the networks through which biomaterials circulate. Using Google Maps, we visually represented the geographic distribution of these actors. For each de-extinction initiative, we compiled a dataset of actor categories, names, details, and approximate locations. We generated interactive digital maps that indicated where these actors operate.[1] These maps also charted the trajectories along which biomaterials move, illustrating the directional flows of materials, finances, and power.

To illustrate the neocolonial parallels in de-extinction geographies, we overlay de-extinction nodes, networks, and icons (detailed below) onto a historical map of the British Empire from the nineteenth century, printed as a reference map in the early twentieth century (Asprey & Co, 1924). This overlay draws a parallel between historical colonisation and contemporary scientific practices. It also shows how major centres of technoscientific development, established during Victorian Britain, have shifted westward – largely to the coastal United States – facilitated by the colonial and ideological foundations of that era. This hybrid mapping technique provides a clear visualisation of the data while deepening the historical and political context of the research.

Mapping mammoths

The figure of the woolly mammoth (*Mammuthus primigenius*) has been walking through the collective cultural imaginaries of humans, on the edges of perception, unreal and material, for millennia (O'Riordan, 2017). In Eleanor Arnason's 2010 novella, *Mammoths of the Great Plains,* this haunting is beautifully realised in an Indigenous counter narrative in which mammoths and people co-exist in the Great Plains of the United States and Canada, aligning a site of the mammoth's natural history with a postcolonial imaginary of North America. The affective register, and weaving of counterfactual history and decolonial imaginary, resonates with the final alienating appearance of the mammoth in the 2004 documentary film *Soy Cuba, O Mamute Siberiano*, which examines the making of the 1964 Cuban film, *Soy Cuba*. The documentary deconstructs the political propaganda and nationalism in the making of *Soy Cuba* only to ultimately align itself with Russian nationalism through a lament for the mammoth. Reflecting the historical and ongoing tensions between nations, the figure of the mammoth looms in both American and Russian narratives. Potentially the most charismatic of the extinct megafauna, the mammoth does a lot of work.

The mammoth persists through different representational and bio-media, emerging at the intersection of the collective human conscious and biomaterials. Its likeness has appeared in human visual cultures since Lascaux; one of the earliest examples in the United States is a mammoth figure inscribed into the ivory of a mammoth bone (Dell'Amore, 2011). The melancholia of the mammoth exists in specific cultural histories (Wrigley, 2023), and, more broadly, as it is virtualised and universalised through global media. This is exemplified by the animated character Manny from *Ice Age*, underscoring the mammoth's persistent presence in popular culture. This affective animation extends to practical efforts like Pleistocene Park, a Siberian nature reserve in the Sakha Republic dedicated to restoring 'the high productive grazing ecosystems in the Arctic' (Pleistocene Park, 2024). The park, shown in Figure 1 via an elephant icon (Siberia), unites biotechnology, conservation, and Russian national identification with the mammoth, its project page visually projecting the mammoth onto a terrain teeming with living herbivores that have already been reintroduced. Mammoths have been enlivened for centuries through stories, images, film, animation, and, more recently, genome sequences. As Searle (2020) indicates, mammoths mediate conservation biotechnologies, producing knowledge in environmental and life sciences. They are the exemplar figure of charismatic megafauna – or as Wray (2019) would have it – the necrofauna.

Mammoth findings are well-documented in both science reporting and mainstream media, partly due to their spectral presence in the public imagination. Such findings range from the discovery of their remains to breakthroughs in their genomic makeup. Mammoth specimens often receive names based on their discovery location (e.g. Malolyakhovsky Mammoth, Yuka Mammoth, Yukagir Mammoth) or the discoverer (e.g. Adams Mammoth, Jarkov Mammoth). In genomics research, however, mammoth samples are designated by specimen numbers (e.g. M1 – M26). This practice not only serves scientific classification but also underscores a rhetorical distinction between the specific mammoths used in research and the symbolic figure envisioned for resurrection. This distinction reflects broader cultural and political dynamics, as the mammoth's reappearance in public and scientific discourse evokes themes of colonialism, nationalism, and neocolonial patterns.

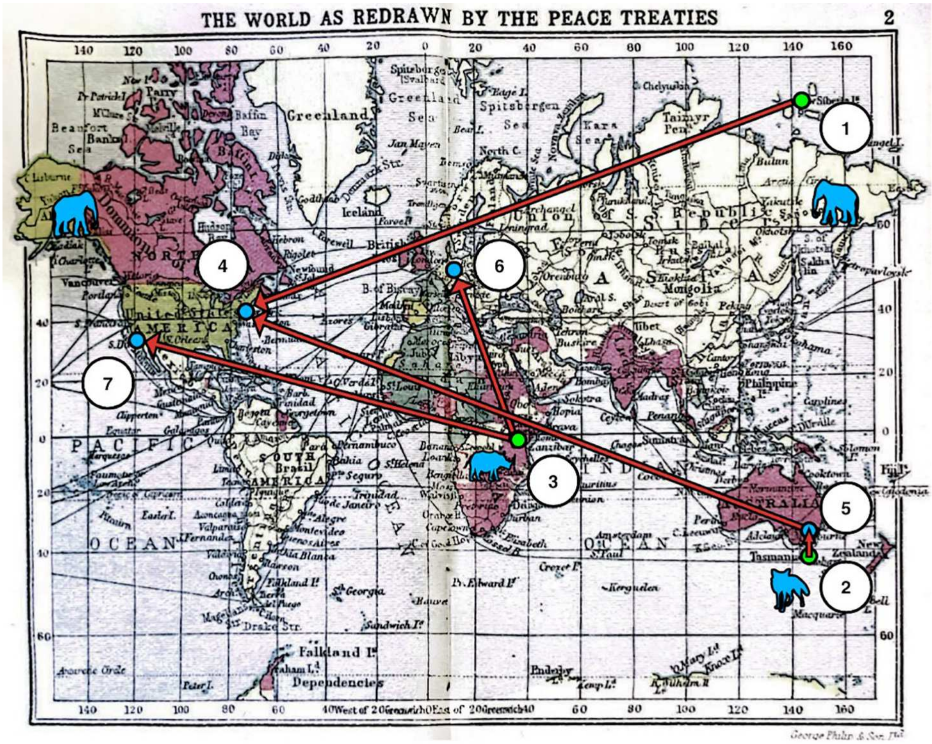

Figure 1. Visualising de-extinction networks over colonial geographies.

Notes: Asprey & Co. (1924); this map visualises the global network of actors and resources involved in de-extinction initiatives, overlaid on a historical map of the British Empire. The legend details extraction sites, project locations, and reintroduction regions. Nodes: 1. Siberia, mammoth extraction site; 2. Tasmania, thylacine extraction site; 3. Kenya, rhino extraction site and Ol Pejeta site; 4. Boston, site of Colossal Bioscience Labs and George Church Labs; 5. Melbourne, site of TIGRR; 6. Berlin, BioRescue project site; 7. San Diego, San Diego Frozen Zoo site. Icons: Elephant (Alaska): Mammoth reintroduction site; Elephant (Siberia): Mammoth reintroduction region, Pleistocene Park site; Thylacine: Thylacine reintroduction region; Rhino: Rhino reintroduction region.

Mammoth de-extinction joins the colonial and neocolonial history of the Arctic, a region long exploited through the displacement of Indigenous communities, economic disparity, and the labour of marginalised workers. Unlike the thylacine and northern white rhino, mammoths were not driven to extinction through colonisation. Siberia, where mammoth remains are often found, was colonised by Russia in the sixteenth century, while Alaska was colonised by Russia in 1784 and sold to the USA in 1867. USA resource extraction of gold in Alaska mirrors patterns seen in British colonies like Australia (1788), Tasmania (1803), and Kenya (1901). Power and resources flow back to key actors through resource control, management, and prospective conservation initiatives. As Wrigley (2023, p. 4) documents, before perestroika (1985–1991), the state incentivised Soviet citizens to settle in the Arctic, contributing to the displacement and forced assimilation of Indigenous reindeer herders into a 'homogenous Soviet Culture'. After the reform movement and the USSR's dissolution, state support dried up as Russia pivoted to economic pursuits in the

Arctic. This pivot effectively abandoned those settled there to harsh conditions, job scarcity, and a skyrocketing cost of living, while transforming the region into a site for extracting natural resources, such as oil, natural gas, minerals, and mammoth remains (Wrigley, 2023). This legacy of exploitation persists in contemporary conservation efforts, which often mask continued resource extraction.

Building on this legacy, efforts to extract mammoth remains – for profit or research – depend on the labour of marginalised regional workers. In Russia's Republic of Sakha (Yakutia), average monthly salaries are RUB40,000 (£450), while a single mammoth tusk can sell for over $30,000 (£22,700) depending on its condition (Ferris, 2020). Incentivised by poverty rather than profit, teams of regional workers spend months in the New Siberian Islands (Figure 1, node 1), excavating these tusks, and often forgoing traditional and religious beliefs surrounding the remains (*Genesis 2.0*, 2018). If the workers fail to retrieve ivory, they are not paid for their labour. This neocolonial extraction leverages the labour of the oppressed to funnel resources to those in power. Around 3 million hectares of protected areas in Yakutia are dedicated to conservation efforts aimed at preserving biodiversity. However, these efforts are often overshadowed by the profitable resource extraction industry, perpetuating historical exploitation and inequality.

Money and resources from mammoth remains are funnelled out of the Arctic, further alienating its inhabitants from the products of their labour and their land. Of the 100 tonnes of mammoth tusks extracted from the Yakutia region annually, roughly 80 per cent are exported to China, where they are carved and resold for up to £750,000 (Weiss, 2019; Ferris, 2020). In contrast, de-extinction and genomics profit by controlling the data that these remains produce. Decades of mammoth genomic data is stored through International Nucleotide Sequence Database Collaboration, which comprises the National Institute of Health's (NIH) GenBank, GenBank at the National Center for Biotechnology Information (NCBI), the European Nucleotide Archive (ENA), and the DNA DataBank of Japan (DDBJ). This data is circulated within technoscientific centres of colonial power, establishing a global network of control and resource extraction. These practices underscore the connections between scientific advancement and the economic exploitation rooted in colonial histories.

Mammoth genomics research, central to de-extinction, is in the orbit of synthetic biology, genetic engineering, and cloning (Shapiro, 2016). In 2006 and 2007, researchers published 13 woolly mammoth mitochondrial DNA genomes. In 2008, Gilbert et al. leveraged high-throughput DNA sequencing to assemble one of the largest ancient mitochondrial DNA (mtDNA) datasets to date, comprising nearly 300,000 nucleotides of unique sequence data from 18 individual samples. In November 2008, Miller et al. from Penn State sequenced the mammoth's nuclear genome, identifying deviations from the

African elephant's genome. Subsequent studies explored the species' demographic and genetic decline, Arctic adaptations, and relationships to existing elephant species. Enter de-extinction.

Colossal Biosciences (Figure 1, node 4) has emerged as the public face of mammoth revival. Laura DeFrancesco (2021) details the company's process: identifying the genes that distinguish a woolly mammoth from an elephant, its closest genetic relative, editing those genes into an Asian elephant embryo using CRISPR, and gestating the gene-edited embryo to term. Colossal's team has identified 60 genes that confer mammoth-like features, including cold tolerance. Colossal (2024) plans to create a hybrid Asian-Woolly Mammoth embryo and transfer it to an African elephant surrogate, whose larger size makes them more suitable for carrying the hybrid to term. Although African elephants share fewer genetic similarities with mammoths, they are classified as threatened while Asian elephants are endangered. By engineering cold-resistance traits in Asian elephants, Colossal aims to mitigate their extinction risk, aligning with the company's conservation-driven mission.

Through the visualisation (Figure 1) and our underpinning digital maps (Appendix), we show the locations of primary actors. These include Colossal Biosciences, which has labs across the United States; Revive & Restore in California, which transferred its nine-year mammoth revival project to Colossal in 2021; and Pleistocene Park in Siberia, a potential habitat for revived mammoths. Mammoth materials circulate from the New Siberian Islands to biotechnological centres in the United States and Europe via global trade routes, moving through research and cultural institutions such as universities, labs, museums, and zoos. Scientists use digitally sequenced mammoth mRNA and nuclear genomes available online through GenBank in Bethesda, Maryland. These genetic materials are then used in research conducted on Asian elephants, kept at the Kodanad Elephant Training Centre in India. The project aims to reintroduce mammoths to their imagined Arctic habitats, exploring locations in Siberia and Alaska (Druckenmiller, 2022). Our mapping illustrates the neocolonial patterns of resource and data extraction, highlighting the power dynamics and exploitation embedded in these global networks.

The reintroduction of mammoths to the Arctic connects the project to neocolonialism within the established framework of conservation. Colossal initially hinted at releasing the mammoths in Pleistocene Park, promising to defuse the impending carbon bomb and foster post-Cold War technoscientific collaboration between the United States and Russia. However, Russia's 2022 invasion of Ukraine heightened geopolitical tensions. Consequently, the project now imagines a reintroduction site in Alaska, marked by the elephant icon (Alaska) in the visualisation. This shift politically confines the data, research, and the initiative's product – the mammoth – within the United States while extracting resources from regions like Siberia that supply essential materials for the project. This decision will impact local industries and communities as questions arise around the intersection between mammoth territory and other designated land, such as the National Petroleum Reserve or those belonging to Indigenous nations (e.g. Aleut, Yupik, and Inuit). Conservation initiatives to prevent mammoth hunting could further drive the model of resurrected mammoth conservation to exclusionary conservation as major actors will benefit from research, resources, and tourism at the expense of local communities. The mammoth initiative demonstrates the potential risks of exacerbating neocolonial power imbalances through conservation and resource management.

Mapping tigers

The thylacine (*Thylacinus cynocephalus*), or Tasmanian Tiger, was an apex predator (prior to humans) native to Tasmania and Southern Australia. The first modern thylacine appeared approximately 2 million years ago. Around 2,000–3,000 years ago, the thylacine became extinct on the Australian mainland, likely due to competition with feral dogs (dingoes) introduced by humans in prior millennia (Australian Museum, 2021). In Tasmania, the species' population declined rapidly after British colonisation in 1803. Authorities and settlers saw the thylacine as a threat to livestock, categorising it as a pest and intentionally eradicating it. The last known thylacine, 'Benjamin,' died in captivity in 1936, marking the species' extinction (Stark, 2018).

The thylacine project can be understood as a form of neocolonialism, rooted in the colonial history of its extinction, political tensions, and the narrative of its revival. Unlike mammoth de-extinction, this project aims to repair some of the damage caused by European colonisation. The British began colonising Tasmania in 1803, establishing it for sheep farming and as a penal colony. While sheep numbered over 7 million by 1828, the thylacine, numbering about 5,000, was seen as a threat to them (NAA, 1977). As Franklin (2007, p. 122) argues, 'sheep were essential vectors of Australian colonization'. Between 1888 and 1909, the government introduced a £1 bounty for each thylacine killed, devastating the species. The eradication of the thylacine and its habitat was part of broader colonial policies, which included acts of genocide against the remaining 4,000-15,000 Aboriginal people (Palawa or Pakana), who were also perceived as a threat to the industry. The survivors were incarcerated and placed in camps, with the only remaining Aboriginal people in the region being mixed-race (Madley, 2008). The thylacine's extinction is deeply and symbolically tied to the colonial violence perpetuated against the region and its people.

While representing the region's colonial past, the thylacine has also emerged as an icon of postcolonial Tasmania, featured on its coat of arms. These tensions are evident in earlier revival attempts. Documenting the controversy surrounding the Australian Museum's 1999 initiative, Fletcher (2008) notes that the effort 'inevitably caused observers to reflect on why it disappeared in the first place and re-opened all the old wounds caused by the deliberate extinction of the Tasmanian tiger during the colonial period'. Critics accused the New South Wales government of investing large funds to fix a problem that it had ostensibly caused through imperialism. To belay this image, political and scientific attempts have upheld the revived thylacine as a cyborg figure of a postcolonial Australia. Fletcher (2008) remarks,

> [the thylacine's] story bridges colonial Australia and modern Australia; it is the crucial pivot point between the European settlers' intense dislike of the rare and the weird, and a postcolonial Australia in which valorization of indigenous species constitutes a vital source of culture and identity.

However, the thylacine remains a steadfast representation of the region's colonial history. Its revival and the speculative rewilding of Tasmania will not restore the ecosystem for the Tasmanian Aboriginals, but it presents an alluring narrative that promises salvation from the irreparable damage of Western imperialism.

The contemporary thylacine de-extinction project occupies a similar narrative. While the research is primarily conducted through the Thylacine Integrated Genomic Restoration Research (TIGRR), Colossal Biosciences has also backed the project with $10,000,000, funnelling the project's materials, data, and capital back to the United States (Mannix, 2022). Although thylacine biomaterials circulate within Australia and Tasmania, uniting the region, species, and its materials, they are managed through colonial-era institutions. The key actor in the network, TIGRR, is hosted at the University of Melbourne, and the previous project was hosted at the Australian Museum; both were established by the British during the colonial era that oversaw the ravaging of Tasmania. These technoscientific initiatives, while aiming to make reparations, reproduce neocolonial patterns by following the same resource flows that enabled their creation, now reorienting towards the United States as a contemporary world power.

The thylacine operates as an ideal de-extinction candidate, perhaps the most promising of the three, with rich DNA sources, close living species, and marsupial biological characteristics. Before its extinction, thylacine young, embryos, tissues, bones, and teeth were preserved in institutions and private collections worldwide. The *International Thylacine Specimen Database* documents 803 known specimens from 588 source animals. Major museums acquired samples internationally, with the United Kingdom holding the largest number (24), followed by Germany (17) and mainland Australia (12 or 16 including Tasmania) (Sleightholme and Campbell, 2018, p. 507). The colonial patterns within material circulation emerge as these remains are routed from Tasmania (Figure 1, node 2) to institutions in the United Kingdom and Western Europe. Many eighteenth-century soft tissue specimens were preserved in ethanol, maintaining DNA quality (Stark, 2018). Despite contamination, contemporary sequencing can map around 80% of the original data (Feigin et al., 2017). The quantity and quality of its preserved DNA, its adaptability as a marsupial, and its symbolic representation of human impact on its demise make the thylacine a key figure for de-extinction efforts.

Contemporary thylacine de-extinction projects span over two decades. In 1999, Michael Archer, then Director of the Australian Museum in Sydney, launched the museum's thylacine cloning project (Greer, 2009). By 2002, the team successfully replicated thylacine nuclear and mitochondrial DNA using polymerase chain reaction (PCR), enabling the reproduction of large quantities of thylacine genes. However, the quality of the replicated DNA was too low to complete the proposed genomic library, sequence the thylacine genome, or create artificial chromosomes (Campbell, 2022). The project was ultimately abandoned in 2005.

In 2018, Dr. Andrew Pask, the TIGRR Lab head, sequenced the thylacine genome (Feigin et al., 2017; Colossal, 2024). By 2022, the TIGRR Lab at the University of Melbourne (Figure 1, node 5) partnered with Colossal Biosciences on the current thylacine de-extinction project. The thylacine genome was updated and reported as 'the highest quality extinct genome for any species' (TIGGR, 2024). Researchers also sequenced a 'platinum level' genome of the fat-tailed dunnart (Sminthopsis crassicaudata), a close relative of the thylacine and easily bred. Platinum level, a standard promoted by Illumina, a global leader in genomic sequencing, promises gap-free genome sequences. This resource will 'provide the living cells and genomic template' to create a functional Tasmanian tiger genome and eventually a complete specimen (TIGGR, 2024).

Marsupials are important in the context of mammalian de-extinction as they offer a quicker and more adaptable medium than other mammals. They are small, numerous, and have short gestation periods, with development completed in external pouches. TIGGR (2024) explains:

> De-extinction efforts for marsupials have a distinct advantage over other mammals. All marsupials give birth to tiny young regardless of the size of the adult, so the fetus outgrowing the mother's uterus is not a concern.

Thus, the existent dunnart species could host a (much larger) thylacine. Additionally, marsupials are very tolerant of fostering pouch young of other species, allowing a thylacine to complete its development in another marsupial's pouch.

The current project is still in its early stages. Both organisational websites outline a similar four-stage process with slight variations: sequencing, genome editing, cloning, and surrogacy. Colossal Biosciences (2024) aims to sequence the genomes of the thylacine's closest living relatives to build 'genotype to phenotype pipelines for marsupials to identify genes that will enhance the recipient host genome to become "thylacine-like"'. They will establish compatible cell lines and induced pluripotent stem cells (iPSCs) for CRISPR editing, sequencing, stem cell derivation, gametogenesis, phenotypic assays, and somatic cell nuclear transfer (SCNT). The next step involves applying 'CRISPR and other genome engineering technologies to insert Thylacine genes into the genome of a Dasyurid'. This is a broad category referring to a grouping of marsupials of about 70 species. Finally, they will use SCNT to transfer a nucleus from a thylacine-like cell into a Dasyurid egg, stimulate embryonic growth, and implant the embryo in a surrogate to gestate for 42 days, charting its birth and maturation.

The TIGRR (2024) lab focuses on marsupial genomics and reproduction, refining methods for deriving marsupial stem cells and developing assisted reproductive techniques. The lab aims to establish stem cells applicable to all marsupials for biobanking genetic diversity. This bioinformatics project will compare genomes to identify necessary edits to the numbat marsupial genome to create a 'thylacine' cell. The lab has derived stem cells for its model species, the fat-tailed dunnart, and aims to gene-edit a numbat cell, fuse it with an empty dunnart egg, and create a 'thylacine' embryo. Though TIGRR's approach differs from Colossal's, the future stages align: transferring the embryo to a surrogate, with the newborn being either bottle-fed or transferred to a larger marsupial pouch. In this reproductive imaginary, the thylacine, although ostensibly the odd marsupial out, bridges the mammoth and rhino projects, in effect the lab rat for de-extinction writ large. The high-quality genomic data and marsupial gestation process make it the most promising candidate of the three, and advances in this project could potentially accelerate the others.

This visualisation (Figure 1) and digital maps (Appendix) illustrate the actors and networks involved in the thylacine de-extinction project through the historical circulation of materials. TIGRR sequenced the thylacine genome by extracting DNA from a 108-year-old, alcohol-preserved specimen from Museums Victoria, Australia (Feigin et al., 2017). While this specimen was sampled locally, 'wet' specimens are preserved in 15 museum collections (Sleightholme and Campbell, 2018). To sequence the numbat genome, scientists sampled tissues from a numbat at Perth Zoo, euthanised for medical reasons in 2019 (Peel et al., 2022). Colossal and TIGRR plan to fuse the edited numbat-cum-thylacine cell with a dunnart egg and implant it in a surrogate. This stage is theoretical, with ongoing studies on dunnart sex chromosomes and postnatal development using samples from the breeding colony at The University of Melbourne's School of BioScience (Cook et al., 2021; Marín-Gual et al., 2022). Currently, samples are circulated within Australia, but materials will be transferred to the USA for Colossal's involvement. Ultimately, Colossal (2024) aims to reintroduce the thylacine in Tasmania, indicated on the visualisation (Figure 1) through the thylacine icon, describing it as an island that 'has remained relatively unchanged, providing the perfect environment to reintroduce the thylacine and enabling it to reoccupy its niche'.

Thylacine materials flow through temporal and spatial networks. Once dispersed across the imperial geographies of scientific and natural history collections, these remains are now directed to biotechnology facilities in the USA and Australia. Biomaterial production from the bodies of numbats and dunnarts is concentrated in Melbourne. The intended rewilding is specific to Tasmania, a complex and contested territory within the global politics of Australia, indigeneity, and settler colonialism, where the thylacine's extinction is embedded.

Mapping rhinos

Like the thylacine, northern white rhino (*Ceratotherium simum cottoni)* extinction and de-extinction narratives are shaped through histories of conflict, settler colonialism, and postcolonial politics. The northern white rhino formerly inhabited north-western Uganda, South Sudan, eastern Central African Republic, and north-eastern Democratic Republic of the Congo. These regions have histories marked by enslavement and brutal colonisation through British, French, and Belgian imperialism from the seventeenth to the twentieth centuries. The species has been hunted for its meat, and more often for its ivory, which has funded colonisation and conflict across its habitat. Rhino horn has been a trade commodity for over two thousand years, with its market value intensifying significantly in the nineteenth and twentieth centuries, as evidenced within the East India Company records (Martin and Vigne, 1997). The species has also been significantly impacted by conflict and war in the postcolonial period since the mid-twentieth century.

Until the late twentieth century, the northern white rhino inhabited central and eastern regions of sub-Saharan Africa. It is one of two subspecies of white rhino (or wide-lipped rhino), although researchers debate whether these are distinct species or subspecies. The northern white rhino is near extinction, with only two animals alive as of October 2024, Najin and Fatu. In contrast, the southern white rhino is the most populous, with approximately 17,000 living animals (Emslie and Brooks, 1999). There are five subspecies of rhino, and the species appeared between 5 and 14 million years ago, although taxonomy and genus are disputed. Many subspecies remain extant. Rhinos are the second-largest mammal species, primarily grazing on grasslands and savannahs. The northern white rhino is currently functionally extinct: individual animals are alive, but their numbers are below the threshold for species survival (Säterberg et al., 2013). This status exemplifies the difficulty in defining extinction, as noted by Searle, reflecting the northern white rhino's existence as both a past and potential future species.

The species is believed to have become extinct in the wild around 2008, with the last known wild animals living in the Democratic Republic of the Congo. Since then, the remaining eight rhinos were distributed across the Czech Republic (Nesari and Nabire), San Diego (Angalifu and Nola), and Kenya

(Sudan, Suni, Najin, and Fatu). Currently, only Najin and Fatu remain, and like Benjamin the thylacine they have become poignant 'endling' characters in stories of the anthropocene, as explored by Lydia Pyne (2022). Born in 1989 and 2000 respectively at the Dvůr Králové Safari Park in the Czech Republic, they were shipped to the Ol Pejeta Conservancy in Kenya (Figure 1, node 3) in 2009. At that time, the last male, Sudan, was also living in the conservancy, and unassisted reproduction seemed possible. However, Sudan died in 2018, and the remaining animals do not have reproductive capacity. With a life expectancy of 40 years, the species is likely to become fully extinct within the next two decades.

The Ol Pejeta Conservancy, and similar facilities, reproduce colonial patterns of land ownership, displace local sovereignty, and attract funding and commodification opportunities, largely rendering them elite global and local tourist attractions. During British colonisation, Kenya was transformed into a settler economy, with large tracts of land, including areas now part of Ol Pejeta, appropriated for European agricultural use and wildlife conservation efforts. Though now a designated not-for-profit organisation, Ol Pejeta's (2024) history as a ranch began in 1946 when it was purchased by Lord Delamere, an influential British settler, symbolising the era's land appropriation practices. Rosaleen Duffy (2022, p. 24), and others working in the political ecology of conservation, articulate these through lenses of commodification and securitisation, noting that security-oriented approaches shape wildlife conservation practices, 'with far-reaching consequences for marginalized communities living with wildlife'.

These rhinos, along with other human and non-human animals, exist at the intersection of wildlife trades, conservation, extinction, and de-extinction. The protection and memorialisation of endangered and extinct species, along with the promise of de-extinction, exacerbate the weight of global saviour narratives. When combined with advancements in biotechnology, the militarisation of conservation exacerbates 'the consequences of … heavier levels of enforcement, militarization, and violence at the hands of conservation authorities' (Duffy, 2022, p. 34). Conservancies are further weaponised as conservation extends beyond protection to reintroduction. A highly militarised approach to poaching, including the killing of poachers, is legitimised as biotechnology companies' interests overlay colonial conservation economies focused on charismatic megafauna.

Brock Bersaglio and Jared Margulies's (2021) work examines the commodification of non-human animal memorialisation and afterlife, highlighting concerns about the commodification of extinction and the securitisation of conservation. Their work addresses the neocolonial effects of this securitisation, where arming rangers to protect elite conservation tourism makes local lives expendable. They argue that the commodification of the rhino as a lucrative spectacle for super-rich elites, underpinning its position as a de-extinction candidate, drives a militarisation of conservation. In this context, memorialising non-human animals (re)legitimises the killing of humans. Kashwan et al. (2021) reinforce this argument, providing further evidence that demonstrates dominant conservation models enact violence against the world's most vulnerable populations. This intersection of commodification, securitisation, and violence underscores the neocolonial dynamics at play.

The BioRescue Consortium (Figure 1, node 6) connects key actors in the northern white rhino IVF/surrogacy de-extinction nexus. This includes the Kenya Wildlife Service; Ol Pejeta Conservancy in Kenya; Safari Park Dvůr Králové in the Czech Republic; Leibniz Institute for Zoo and Wildlife Research (Leibniz-IZW) in Germany; Max Delbrück Center for Molecular Medicine in Berlin; Avantea in Italy, a laboratory specialising in advanced animal ARTs; the University of Padua in Italy; and Kyushu University in Japan. Materials and methods are circulated through this network. In 2019, researchers collected eggs from the two remaining females and used banked sperm from dead males to create the first viable northern white rhino embryos (blastocysts) *in vitro*. These and further developed embryos are stored in liquid nitrogen at minus 196 degrees Celsius in Italy. While surrogacy trials with southern white rhinos have yet to begin, proof-of-concept testing is underway, with the first successful IVF rhino birth occurring in September 2023.

A parallel alternative to the IVF/surrogacy track involves stem cell research, reprogramming somatic cells into pluripotent cells capable of generating gametes. Researchers have applied this technique to northern white rhino cells, using skin cells induced into pluripotency to create primordial germ cell-like cells (PGCLCs), which can potentially develop into functional gametes. Known as Stem Cell Associated Technologies (SCAT), these processes preserve genomes as pluripotent stem cells, offering the potential for iPSC-derived germ cells in assisted reproduction (Ben-Nun et al., 2011). The SCAT research initiative, based in California (Figure 1, node 7), involves the San Diego Frozen Zoo collection, the Scripps Institute, and the University of California Institute of Reproductive Medicine, where iPSC work on the northern white rhino occurred. This global network of labs, conservancies, and sample collections extends through Africa, Europe, and North America, exemplifying the collaborative nature of de-extinction efforts. However, it also mirrors neocolonial patterns, with key research and technological advancements concentrated in European and North American institutions. This concentration of power and resources in the Global North not only reflects historical imbalances but also perpetuates a dynamic where the Global South remains primarily a source of biological materials and field sites (Merson, 2000).

We have traced the northern white rhino initiative's actors and materials across multiple continents, with the living animals in Kenya, embryos in Italy, and stem cells in the United States. The networks of people and organisations span the same regions, with multiple actors working across the United States, Europe, Asia, and Africa. The individual animals have also travelled widely. For example, Sudan (the rhino) travelled under sedation from Sudan to the Czech Republic via boat, train, and truck, and then by plane and truck to the Ol Pejeta conservancy in Kenya. Rhinos have travelled to the United States and back, and to Africa or Europe, on specially chartered flights and in containers. This movement of animals and biological materials underscores the global scale and logistical complexity of de-extinction projects. It further illustrates how these scientific advancements rely on the ongoing influence of historical colonial patterns of global resource extraction and circulation.

Conclusion: mapping conservation narratives, biotechnology, and neocolonial networks

Our preamble at the start approaches de-extinction through the lens of science fiction and fantasy, acknowledging the power and apprehension surrounding global technoscience interventions. The size and ambition of Colossal Biosciences is printed on the label, and the rhetoric of gods is amplified throughout science communication and media coverage. Stewart Brand's quote, 'We are as Gods,' originally about informatic technologies in 1968, is now recycled in the context of de-extinction, suggesting that technoscience assumes omnipotence. This power is fuelled by the historical legacies of colonisation, continuing to drive money and resources from the peripheries of former empires to contemporary technoscientific centres.

Across the three de-extinction initiatives examined here, the promise of restoring lost species operates in historically colonised and exploited regions. This promise obscures the role of Western technoscience in perpetuating the injustices of extinction and climate change, rooted in these histories. To make this plain, we situate de-extinction within a postcolonial STS framework informed by feminist STS, analysing the neocolonial patterns and power structures of conservation and biotechnology, including reproductive technology.

Our research is structured around three key questions: What networks emerge when mapping de-extinction's actors, material flows, and technological developments? How do these networks reflect colonial patterns? How do conservation initiatives and biotechnological developments reinforce these power dynamics? Our mapping offers a visual summary of the extensive networks of de-extinction, illustrating their connections to colonial histories. Through the analysis, we show how these networks reflect the power dynamics in conservation initiatives and biotechnological advancements.

We articulate the neocolonial networks that emerge to reinforce the intersecting frames of conservation and biotechnology. This perspective reveals that de-extinction initiatives, recognised for their charismatic candidates, are deeply entangled with conservation narratives promising ecological repair and biodiversity restoration. The reproductive practices involved – IVF, surrogacy, SCNT, iPSCs, and genetic editing – justify and drive the flow of materials and species from bioprospective extraction sites in formerly colonised regions to Western technoscientific centres. Conservation and biotechnology, thus reinforce historical power dynamics and colonial legacies through technoscientific practices. Our research contributes to postcolonial feminist STS, showing that while conservation aims for ecological restoration, and biotechnology focuses on assisted reproduction and genetic engineering, these aims synthesise to reinforce geopolitical control and resource exploitation from historically marginalised regions.

Our empirical analysis is focused on the woolly mammoth, the thylacine, and the northern white rhino, representing de-extinction initiatives rooted in Siberia, Tasmania, and Kenya. The visualisations included a historical map overlayed with de-extinction actors and networks (Figure 1) and an interactive digital map for each initiative (Appendix), illustrating the colonial flows embedded in contemporary technoscientific practices. This mapping highlighted the intersections between conservation efforts and advancements in reproductive and genetic technologies, tracing the persistent influence of colonial legacies. In considering the cultural significance and historical context of each species' extinction, we underscore how de-extinction projects are not just scientific endeavours but also mechanisms of ongoing geopolitical influence and resource management.

De-extinction advocates link their projects to conservation and climate narratives through concepts such as rewilding, carbon sequester, and habitat and species preservation. In the mammoth imaginary, returning the species to Siberia or parts of Alaska promises to restore the tundra. De-extinction actors argue that mammoths, by trampling snow and grazing, will restore the grasslands ecosystem and prevent the thaw and release of carbon trapped in the permafrost. Similarly, the thylacine project claims that reintroducing this apex predator to its native environment in Australia will contribute to 'rewilding' by removing weak and sick individuals, maintaining balance among competitors, and ensuring species diversity (Colossal, 2024). This is expected to reverse the trophic downgrading of the region, addressing issues such as disease proliferation, wildfires, carbon sequestration, invasive species, and disrupted biogeochemical cycles. Advocates for the northern white rhino argue that the loss of this keystone species causes significant ecosystem disturbances. The project aims to establish a self-sustaining, genetically healthy population in Kenya (indicated in the visualisation through the rhino icon) that can be reintroduced to the wild (BioRescue, 2024).

However, these idyllic narratives are disrupted by the present-day impact of de-extinction projects, which perpetuate neocolonial practices by controlling land, resources, and marginalising local communities. Through the lens of

Prasad and Harding, conservation is upheld as a legitimate scientific authority but is embedded in Western colonial values. As Prasad (2022, p. 20) explains, modern science enacts the 'god trick,' presenting itself as both a product of Western culture and as a 'culture of no culture,' obscuring its colonial roots. Conservation, framed as ecological restoration, often reinscribes these dynamics by prioritising global technoscientific interests over local sovereignty, perpetuating what Harding calls the 'residues and resurrections' of colonial science. This critique establishes the foundation for examining the intersection of de-extinction and biotechnological advancements.

The narratives surrounding conservation and climate change also encompass biotechnological advancements, implicit goals in de-extinction research. For instance, Colossal's (2024) mammoth project aims not only to restore the Arctic ecosystem and sequester carbon but also to advance CRISPR editing. Similarly, the thylacine initiative emphasises marsupial biobanking and ARTs, promising 'the development of gestation and maturation devices that can support any marsupial'. The rhino project further drives progress in IVF and stem cell research. These initiatives underscore the dual narrative of ecological restoration and technoscientific progress.

Yet, these advancements are prescriptive, not neutral. As Franklin (2013) argues through the lens of feminist STS, reproductive technologies and biocapital intertwine, reinforcing historical gendered and colonial power dynamics and exploitative practices. They commodify life forms, turning them into economic assets within this framework. These power dynamics manifest in the extraction and circulation of resources, as described by Waldby and Mitchell (2006) and Franklin (2013). Key actors like Colossal Biosciences (United States), TIGRR (Australia), and the BioRescue Consortium (Europe) act as nodes in global networks, facilitating the flow of biomaterials, data, and capital (Figure 1). Mammoth de-extinction operates as a global technoscientific imaginary, linking Alaska and Siberia in post-Cold War conservation efforts, despite sourcing remains from Siberia (Wrigley 2023). Meanwhile, the thylacine and rhino projects, though tied to national contexts, reflect colonial legacies. Thylacine remains are held in Western institutions, tracing back to British colonialism in Tasmania. Rhino materials are extracted from Central Africa, reframing the region as a site of imagined future restoration, while undermining Indigenous sovereignty and self-determination.

Like Dorothy, we and other de-extinction researchers, face a dark and unknowable future teeming with strange animals. Unlike Dorothy, we are also confronted with the dark and knowable past of colonialism. In synthesising the empirical analyses of the woolly mammoth, thylacine, and northern white rhino, this paper illustrates that de-extinction initiatives, ostensibly aimed at ecological restoration, perpetuate neocolonial power dynamics. These projects synthesise conservation narratives with the advancement of biotechnology, driving the circulation of biomaterials, data, and capital among key actors, such as Colossal Biosciences, TIGRR, and the BioRescue Consortium. The networks are further structured through research and cultural institution actors, including universities, labs, museums, and zoos. Resources flow from extraction sites in regions like Siberia, Tasmania, and Kenya to these Western technoscientific centres. By analysing de-extinction as one iteration of biotechnological development, we intervene in postcolonial science and technology studies to demonstrate how contemporary Western technoscience perpetuates historical patterns of geopolitical control through enduring neocolonial networks.

Note

1. For interactive digital maps and images, see Appendix.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes on contributors

Avey Nelson is an Assistant Professor at the University of Sussex, specialising in rhetoric and composition, science and technology studies, and the digital humanities. Their work examines power, surveillance, and marginalisation, from educational technology (Enculturation, 2022) and online privacy (Lateral, 2019) to barriers faced by transgender students in United Kingdom higher education (Sexualities, 2023). They also research the interplay between academia and the creative industries, studying income guarantees (Creative Industries Journal, 2024) and collaborating on theatre projects that reimagine classical plays for queer communities.

Kate O'Riordan is Professor of Digital Culture and Pro Vice Chancellor for Education and Students at the University of Sussex, and the co-author of Furious: Technological Feminism and Digital Futures (Pluto, 2019) with Professor Caroline Bassett and Professor Sarah Kember. They have published widely on digital media and cultures of science and technology including Unreal Objects (Pluto, 2017) and The Genome Incorporated (Ashgate, 2010).

ORCID

Kate O'riordan http://orcid.org/0000-0002-9419-2239

References

Asprey and Co., Ltd. (1924) *Asprey's Atlas of the World: A Series of 145 Coloured Plates with a Geographical and Statistical Summary* (London: Asprey and Co).

Australian Museum (2021) Thylacine. Available at https://australian.museum/learn/australia-over-time/extinct-animals/the-thylacine/ (accessed 6 October 2023).

Ben-Nun, I. F., Montague, S., Houck, M., et al. (2011) Induced pluripotent stem cells from highly endangered species, *Nature Methods*, 8(10), pp. 829–831. doi:10.1038/nmeth.1706

Bersaglio, B. and Margulies, J. (2021) Extinctionscapes: spatializing the commodification of animal lives and afterlives in conservation landscapes, *Social & Cultural Geography*, 23(1), pp. 10–28. doi:10.1080/14649365.2021.1876910

BioRescue (2024) Available at http://www.biorescue.org/en. (accessed 1 June 2024).

Bowker, G. C., and Star, S. L. (1999) *Sorting Things out: Classification and Its Consequences* (Cambridge, MA: MIT Press).

Cabral, A. (2019) The computer science behind DNA sequencing, *Science in the News*. Available at https://sitn.hms.harvard.edu/flash/2019/the-computer-science-behind-dna-sequencing/. (accessed 6 October 2023).

Campbell, C. (2022) The Thylacine Museum, *Natural Worlds*. Available at http://www.naturalworlds.org/thylacine/index.htm. (accessed 6 October 2023).

Colossal Laboratories and Biosciences (2024) Available at https://colossal.com/. (accessed 1 June 2024).

Cook, L., Newton, A., Hipsley, C. and Pask, A. (2021) Postnatal development in a marsupial model, the fat-tailed dunnart (Sminthopsis Crassicaudata; Dasyuromorphia: Dasyuridae), *Communications Biology*, 4(1), doi:10.1038/s42003-021-02506-2

DeFrancesco, L. (2021) Church to de-extinct woolly mammoths, *Nature Biotechnology* 39(10), pp. 1171. doi:10.1038/s41587-021-01096-y.

Dell'Amore, C. (2011) Oldest American art found on mammoth bone, *National Geographic News*. Available at https://www.nationalgeographic.com/adventure/article/110622-mammoth-bone-oldest-art-americas-science. (accessed 6 October 2023).

Druckenmiller, P. (2022) Mammoth de-extinction. Available at https://media.uaf.edu/media/t/1_89cy9puy.

Duffy, R. (2022) Crime, security, and illegal wildlife trade: political ecologies of international conservation, *Global Environmental Politics*, 22(2), pp. 23–44. doi:10.1162/glep_a_00645

Emslie, R. and Brooks, M. (1999) *African Rhino: Status Survey and Conservation Action Plan* (Gland, Switzerland: IUCN).

Feigin, C., Newton, A., Doronina, L., et al. (2017) Genome of the Tasmanian Tiger provides insights into the evolution and demography of an extinct marsupial carnivore, *Nature Ecology & Evolution*, 2(1), pp. 182–192. doi:10.1038/s41559-017-0417-y

Ferris, E. (2020) *Russia and the Woolly Mammoth Trade: How Climate Change Drives Illegal Tusk Trafficking* (London: The Royal United Services Institute for Defence and Security Studies).

Fletcher, A. L. (2008) Bring 'em back alive: Taming the Tasmanian Tiger cloning project, *Technology in Society*, 30(2), pp. 194–201. doi:10.1016/j.techsoc.2007.12.010

Franklin, S. (2006) The cyborg embryo: Our path to transbiology, *Theory, Culture & Society*, 23(7-8), pp. 167–187. doi:10.1177/0263276406069230

Franklin, S. (2007) *Dolly Mixtures: The Remaking of Genealogy* (Durham: Duke University Press).

Franklin, S. (2013) *Biological Relatives: IVF, Stem Cells, and the Future of Kinship* (Durham: Duke University Press).

Genesis 2.0. (2018) Directed by Christian Frei (Switzerland: Rise and Shine World Sales).

Genovesi, P. and Simberloff, D. (2020) De-extinction' in conservation: assessing risks of releasing 'resurrected' species, *Journal for Nature Conservtion*, 56, https://doi.org/10.1016/j.jnc.2020.125838

Gilbert, T., Drautz, D., Lesk, A., et al. (2008) Intraspecific phylogenetic analysis of Siberian Woolly Mammoths using complete mitochondrial genomes, *Proceedings of the National Academy of Sciences*, 105(24), pp. 8327–8332. doi:10.1073/pnas.0802315105

Greer, A. (2009) Cloning the thylacine, *Quadrant Online*. Available at https://quadrant.org.au/magazine/2009/07-08/cloning-the-thylacine/.

Harding, S. (1998) *Is Science Multicultural?: Postcolonialisms, Feminisms, and Epistemologies* (Bloomington: Indiana University Press).
Harding, S. (2009) Postcolonial and feminist philosophies of science and technology: convergences and dissonances, *Postcolonial Studies*, 12(4), pp. 401–421. doi:10.1080/13688790903350658
Iacona, G., Maloney, R., Chades, I., et al. (2017) Prioritizing revived species: what are the conservation management implications of de-extinction?, *Functional Ecology*, 31, pp. 1041–1048. doi:10.1111/1365-2435.12720
IUCN SSC (2016) *IUCN SSC Guiding Principles on Creating Proxies of Extinct Species for Conservation Benefit. Version 1.0.* Gland, Switzerland: IUCN Species Survival Commission.
Kashwan, P., Duffy, R., Massé, F., et al. (2021) From racialized neocolonial global conservation to an inclusive and regenerative conservation, *Environment: Science and Policy for Sustainable Development*, 63(4), pp. 4–19. doi:10.1080/00139157.2021.1924574
Katz, E. (2022) Considering de-extinction: Zombie arguments and the walking (and flying and swimming) dead, *Ethics, Policy & Environment* 25(2), pp. 81–103. doi:10.1080/21550085.2022.2071550.
Latour, B. (2005) *Reassembling the Social: An Introduction to Actor-Network-Theory* (Oxford, NY: Oxford University Press).
Madley, B. (2008) From terror to genocide: Britain's Tasmanian Penal Colony and Australia's history wars', *Journal of British Studies*, 47(1), pp. 77–106.
Mannix, L. (2022) Furry tail or fairytale? Thylacine de-extinction bid wins $10 m boost, but critics question science, *The Sunday Morning Herald*, August 16.
Marín-Gual, L., González-Rodelas, L., Pujol, G., et al. (2022) Strategies for meiotic sex chromosome dynamics and telomeric elongation in marsupials, *PLOS Genetics*, 18(2), doi:10.1371/journal.pgen.1010040
Marres, N. (2015) Why map issues? On controversy analysis as a digital method, *Science, Technology, & Human Values* 40(5), pp. 655–686. doi:10.1177/0162243915574602.
Martin, E. B. and Vigne, L. (1997) An historical perspective of the Yemeni rhino horn trade, *Pachyderm*, 23, pp. 29–40.
Merson, J. (2000) Bio-Prospecting or Bio-Piracy: Intellectual property rights and biodiversity in a colonial and postcolonial context, *Colonial Science and the New World System*, 15(1), pp. 282–296.
Miller, J. (2022) When did mammoths go extinct?, *Nature.*
Miller, W., Drautz, D., Ratan, A., et al. (2008) Sequencing the nuclear genome of the extinct woolly mammoth, *Nature*, 456(7220), pp. 387–390. doi:10.1038/nature07446
National Archives of Australia (NAA) (1977) Sheep grazing in Kempton, Tasmania. Available at https://www.naa.gov.au/. (accessed 6 October 2023).
O'Riordan, K. (2017) *Unreal Objects: Digital Materialities, Technoscientific Projects and Political Realities* (London: Pluto Press).
Ol Pejeta Conservancy (2024) Available at https://colossal.com/. (accessed 1 June 2024).
Peel, E., Silver, L., Brandies, P., et al. (2022) Genome assembly of the numbat (*Myrmecobius Fasciatus*), the only termitivorous marsupial, *Gigabyte.* doi:10.1101/2022.02.13.480287.
Pleistocene Park (2024) Available at https://pleistocenepark.ru/. (accessed 1 June 2024).
Prasad, A. (2022) *Science Studies Meets Colonialism*, (Cambridge: Polity Press).
Pyne, Lydia (2022) *Endlings: Fables for the Anthropocene.* (Minneapolis, MN: University of Minnesota Press).
Revive and Restore (2024) Available at https://reviverestore.org/. (accessed 1 June 2024).
San Diego Zoo Wildlife Alliance. 'Frozen Zoo'. (2024) Available at https://science.sandiegozoo.org/resources/frozen-zoo® (accessed 1 June 2024).

Säterberg, T., Sellman, S. and Ebenman, B. (2013) High frequency of functional extinctions in ecological networks, *Nature*, 499(7459), pp. 468–470. doi:10.1038/nature12277

Searle, A. (2020) Anabiosis and the liminal geographies of de/extinction, *Environmental Humanities*, 12(1), pp. 321–345. doi:10.1215/22011919-8142385

Shapiro, B. (2016) *How to Clone a Mammoth the Science of De-Extinction* (Princeton: Princeton University Press).

Simmons, D. (1991) *The Fall of Hyperion* (London: Bantam).

Sleightholme, S. and Campbell, C. (2018) The International Thylacine Specimen Database (6 revision - project summary & final report), *Australian Zoologist*, 39(3), pp. 480–512. doi:10.7882/az.2017.011

Stark, H. (2018) The cultural politics of mourning in the era of mass extinction: thylacine specimen P762, *Australian Humanities Review*, 63, pp. 65–78.

Thylacine Integrated Genomic Restoration Research (TIGRR). 2024. Available at https://tigrrlab.science.unimelb.edu.au/. (accessed 1 June 2024).

Waldby, K and Mitchell, R. (2006) *Tissue Economies: Blood, Organs, and Cell Lines in Late Capitalism.* (Durham: Duke University Press).

Weiss, S. 2019. The climate crisis has sparked a Siberian mammoth tusk gold rush, *Wired.*

Wray, B. (2019) *Rise of the Necrofauna: The Science, Ethics, and Risks of De-extinction* (Vancouver: Greystone Books).

Wrigley, C. (2023) *Earth, Ice, Blood, Bone* (Minneapolis, MN: University of Minnesota Press)).

Yin, R., Kwoh, C. K. and Zheng, J. (2019) Whole genome sequencing analysis, *Encyclopedia of Bioinformatics and Computational Biology*, 3, pp. 176–183.

Zaitchik, A. 2018. How conservation became colonialism: Indigenous people, not environmentalists, are the key to protecting the world's most precious ecosystems, *Foreign Policy*. Available at: https://foreignpolicy.com/2018/07/16/how-conservation-became-colonialism-environment-indigenous-people-ecuador-mining.

Appendix. Interactive digital de-extinction maps

Woolly mammoth map

https://www.google.com/maps/d/viewer?mid=18OkY0un7lHhNu9IvqOTJqSiQ-ZDMDUw&ll=13.910877009928962%2C0&z=2 Thylacine

Thylacine map

https://www.google.com/maps/d/viewer?mid=1JU3vuDoHgsimF9yTyRgGfb86uyzPvOg&ll=1.7610884662093889%2C0&z=2

Northern white rhino map

https://www.google.com/maps/d/viewer?mid=13KrscjsobuKEgfCpWlNjl-YEHbYseew&ll=5.505441738090182%2C0&z=2